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# The unique and extreme vineyards of Santorini Island (Cyclades)

>>> Own-rooted and phylloxera-free vines have been cultivated on the volcanic soil of Santorini for thousands of years. All this time, vines have been cultivated by using two traditional training systems, the 'Kouloura', and the 'Kldefitiko', which are well-adapted to the specific climatic conditions of the island. This first report aims to share the scarce existing knowledge on Santorini's training and pruning systems, looking at some important quantitative and qualitative ripening parameters over four consecutive seasons (2017–2020) and revealing similarities regarding their adaptation to climate conditions on the island. <<<

## ■ The terroir of Santorini

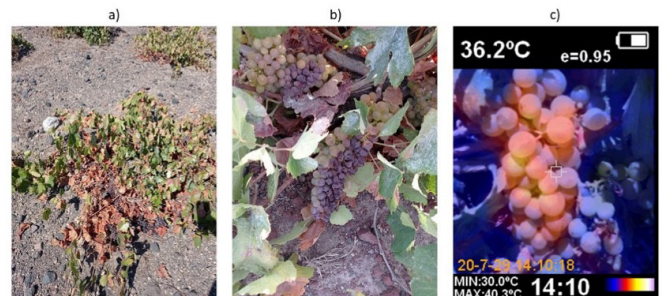
Santorini island (36.3932° N, 25.4615° E) is an active volcanic complex in the Cyclades (Greece), with an area of 79,16 km<sup>2</sup>, of which today 942 ha is covered with cultivated vineyards. The soil on which vines are cultivated was formed from the volcanic explosion which occurred around 1630 B.C. Although limestone is prominent in the southeast part of the island, the soil in the vineyards is mostly sandy and rocky and is composed of pumice, lava and pyroclastic materials<sup>1</sup>.

Santorini has a Mediterranean climate, with mild winters, low rainfall and cool spring seasons characterised by sea breeze from early May until the end of summer. Sea breeze occurs during hot days, preventing fungal diseases spreading on grapevines. Depending on the developmental stage of the vines, strong winds may also be destructive, especially when the grapevines are in their first growing stages, resulting in yield losses. In the summer and near-harvest periods, the weather conditions are extreme: high temperatures (an average of 3 days during summer with temperatures of > 35.0 °C was observed for the 2009–2019 period), heatwaves (which occurred often during summer) (Figure 1a, 1b and 1c) and long drought periods both climatic events affecting yield, berry development and composition and the associated wine aromatic profiles<sup>2</sup>.

However, the phenomenon of 'Anedossa,' a type of floating sea fog that appears at night and lasts until early morning, offers some relief to the vines, as it constitutes the only form of humidity available during the dry summer season. The mean annual rainfall and the mean air temperature during March through August from 2009 to 2019 were 326 mm and 22.01 °C respectively (maximum: 24.96 °C, minimum: 18.55 °C). Furthermore, the rainy season lasted from October till April.

The cultivated vines are not grafted which is largely due to the volcanic soil of the island hindering the survival of phylloxera<sup>1</sup>. Therefore, Santorini vineyards are among the few pre-phylloxeric vineyards in Europe<sup>1</sup>, where the age of the vines generally exceeds 70 years and in some cases 100 years.

Furthermore, stone terraces provide protection from soil erosion, retaining the limited rainwater and reducing the



**Figure 1.** Heat and drought damage on Assyrtiko grapes in Santorini.

effect of high wind speed (Figure 2a). Two unique training systems named 'Kouloura' (basket-shaped) and 'Kldefitiko' (bush-like), have been implemented for centuries helping vines to endure the extreme long-term climatic conditions and the variations per years.

The main cultivated grape varieties (*Vitis vinifera* L.) are Assyrtiko, Aidani and Athiri (white) and Mandilaria and Mavrotragano (red). Additionally, there are forty-nine other varieties, generically called 'Xenoloa' by the locals, which are sparsely grown interspersed among the main Santorinian varieties across the island<sup>1</sup>. Cane pruning is used for Assyrtiko grown under the 'Kouloura' or 'Kldefitiko' systems, because the basal buds of the variety are not usually fertile<sup>3</sup>.

## ■ The traditional training systems

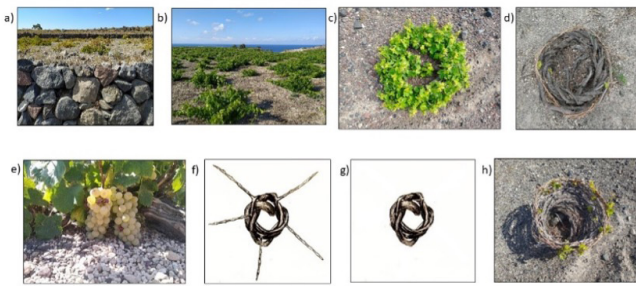
### → The 'Kouloura' training system

Figures 2 (b, c, d, f and g) show 'Kouloura' used in the Santorini wine region. As it resembles a basket, locals also call it 'Kalathi'. It consists of approximately 4–6 canes (primary shoots of the vine) each bearing 8–12 buds (Figure 2f). The canes are woven around the main body of the vine, forming a small basket (Figure 2d and g). The basket is tied close to the soil at a height of 10–20 cm<sup>1,4</sup>. In contrast, 'Niabelo' or 'Koulouba' (the old-style baskets) are created by wrapping year n canes on year n-1 canes (Figure 2h), and it takes several years to build the basket-like structure. These old-style baskets are now only present in small numbers scattered among the vineyards.

Under optimal conditions, the shape of the 'Kouloura' allows the bunches to be positioned inside the basket-like structure (Figure 2e), so that the berries can mature gradually protected from sunlight and the occasional strong winds and resulting sandblasts. The estimated plantation density of Assyrtiko vines varies from 1800 to 2200 vines per hectare, with a mean yield of approximately 2,080 ± 1,180 kg/ha grapes (2017–2020).

### → The 'Kldefitiko' training system

'Kldefitiko' (Figures 3a, 3b, 3c and 3d) is a bush-like training system, achieved by mixed pruning methods. The heights of the vine's trunks range from 20 to 30 cm, and the pruners leave 3–5 canes per vine with 8–10 buds per cane and an equal number of spurs with two buds.

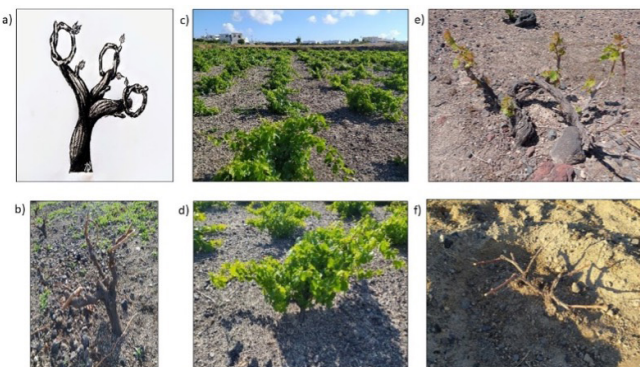


**Figure 2.** Stone terraces (a); ‘Kouloura’ training system (b, c, d, f and g); shaded cv. Assyrtiko bunches positioned underneath the leaves (e); ‘Koulouba’ training system (the old-style basket) (h).

These canes are then woven around the arms, forming small bracelet-like shapes hanging vertically above the ground called ‘koulouria’<sup>4</sup>. The late pruning and wrapping is done in order to delay bud break, and it also protects the vine from being damaged by the spring winds<sup>1</sup>. ‘Kladeftiko’ is used in areas that are not exposed to strong winds as the system is more sensitive than ‘Kouloura’. It provides better aeration and healthier growing conditions for the grapes, because they are higher up above the soil. However, the vines and the clusters are more exposed to the sun and strong winds than with ‘Kouloura’.

Kladeftiko is not used for all the varieties cultivated on the island, as the vine shoots of some varieties are fragile and cannot be twisted, which could explain the success of cultivars like Assyrtiko which can be twisted. Such varieties, including the Mandilaria cultivar, need to be pruned to produce short canes which each bear 3–5 buds. As a result, the architecture of the vine and its foliage has the shape of a ‘Gobelet’. The vine is 20–30 cm high and has 3–5 small ‘arms’ (Figure 3e and 3f). However, the branches extend horizontally from the trunk and close to the soil. Each ‘arm’ bears a short cane with 3–5 buds, depending on the vigour of the vines. The shoots are not tied to any support system which is similar to the non-trellised ‘Gobelet’ on the island of Pantelleria<sup>5</sup>.

The average density of an Assyrtiko plantation using the ‘Kladeftiko’ training system is approximately 2,000–2,500 vines per hectare, with an average yield of approximately  $2.100 \pm 1.220$  kg/ha (2017–2020).



**Figure 3.** Schematic illustration (a) and view (b), (c) and (d) of ‘Kladeftiko’ training system. Representative examples of a ‘Postes’ training system (e) and (f).

It is interesting to note that no significant differences between the two training systems were recorded in our study (conducted over four consecutive seasons in 2016/2017, 2017/2018, 2018/2019 and 2019/2020) in terms of yield and ripening parameters of representative vineyards on Santorini Island, which could again explain the preference for Assyrtiko.

## ■ Conclusion

The “traditional” training systems, *Kouloura* and *Kladeftiko*, are well-adapted to the particular and extreme climatic and soil conditions of Santorini island, and are part of the authenticity of the landscape/terroirs of this wine region. The question remains whether these training systems and viticultural practices could be adapted to other dry and warm wine regions, given that in 2021 heat and drought damages affected the vines. It is important to learn from traditional viticulture and grape varieties, such as those described in this study, but in the context of climatic deregulation some adaptations could help improve vine resilience, even in traditional vineyards (e.g., by grafting on the appropriate rootstock). These examples show that the adaptation of cultural practices to extreme or evolving climatic conditions is currently a permanent challenge and a matter of managing in an integrated way the interaction between varieties, rootstocks, soil life, training and pruning systems, plantation density, yield/vine and the related exposed leaf area, as well as vineyard and winery economics. ■

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